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FLIGHT REPORT
INTERPLANETARY MONITORING PLATFORM
IMP-II (EXPLORER XXI)

by Frank A. Carr

Goddard Space Flight Center
Greenbelt, Md.

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ABSTRACT

IMP II was launched on October 3, 1964 from Cape Kennedy, Florida, by the Delta 26 Launch vehicle. The apogee achieved was 51,600 n.m., which was less than one-half of the planned altitude. This problem was attributed to the suspected failure of the igniter assembly of the third-stage motor, occurring after about 16 seconds of normal burning.

The angle between the spacecraft spin-axis and the ecliptic plane was reduced by the third-stage malfunction, resulting in a wider range of incident sun-angles during the satellite lifetime. This caused low power output from the solar paddles and over-heating of the silver-cadmium battery.

Spacecraft performance was satisfactory until the +50°C temperature environment (about two months after launch) caused the failure of the battery. Thereafter, the spacecraft operated only during periods of favorable incident sun-angles. In all, about five months of useful data was recorded. As of mid-1965, the spacecraft was operating intermittently with essentially no useful data being obtained. There is some possibility that perhaps as much as a month's more data might be obtained in the future.

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INTRODUCTION

The IMP series is a continuation and an outgrowth of the successful series of GSFC Explorer satellites including X, XII, XIV, and XV. IMP-I, launched on 26 November 1963, attained an apogee of 106,000 n.m., which carried it well into interplanetary space. The spacecraft operated successfully for more than six months (Reference 1) telemetering a wealth of data. The scientific experiments on IMP-I (Explorer XVIII) provided the first direct evidence of a collisionless magnetohydrodynamic shock wave surrounding the earth and its magnetosphere. The spacecraft also provided many data on the nature of the transition region between the magnetopause and shock front; i.e., the magnitude, direction, and variations of the interplanetary magnetic field, and on the energy and fluxes of the solar wind and solar and cosmic rays (Reference 2).

IMP-II, launched slightly more than ten months after the first IMP, carried the same type experiments, but which in many cases were updated and refined, based on data obtained from IMP-I.

MISSION OBJECTIVES

The mission objectives of IMP-II (Reference 3), similar to those of IMP-I, were (1) to study in detail the radiation environment of cislunar space, and to monitor this region over a significant portion of a solar cycle; (2) to study the quiescent properties of the interplanetary magnetic field and its dynamical relationship with particle fluxes from the sun; (3) to develop a solar flare prediction capability for Apollo; (4) to extend knowledge of solar terrestrial relationships; and (5) to further the development of relatively inexpensive spin stabilzed spacecraft for interplanetary investigations. Because of the achieved apogee of only 51,600 n.m., the primary objectives (i.e., monitoring of the interplanetary medium) were not accomplished. However, the spacecraft's nine scientific experiments provided many data from within the magnetosphere which are expected to contribute significantly to the understanding of this region.

LAUNCH

The IMP-B spacecraft was launched (Figure 1) on 3 October 1964 at 2245:00.4 EST (4 October 1964, 0345:00.4 UT). After a successful launch, it was redesignated as IMP-II.

The Delta 26 launch vehicle, designated DSV-3C, consisted of a Douglas Aircraft liquid propellant Thor booster, an Aerojet General liquid propellant second stage, and an Allegheny Ballistics solid propellant third stage. The 30-inch extended low drag aerodynamic fairing was used.

First stage performance was above nominal, and second stage engine performance was good but with a slightly lower than nominal thrust level achieved. First and second stage propellant utilization was 99.7 and 97 percent respectively. At sustainer engine cutoff (SECO), the vehicle velocity was within 3 ft/sec of nominal. The spin rate at second/third stage separation was 80.6 rpm (nominal was 72 ±10% rpm) with some pitch and yaw motions due to the asymmetrical spin rocket arrangement. A malfunction of the third stage occurred about 17 seconds after ignition which resulted in reduced performance and considerable coning of the third stage spacecraft configuration.*

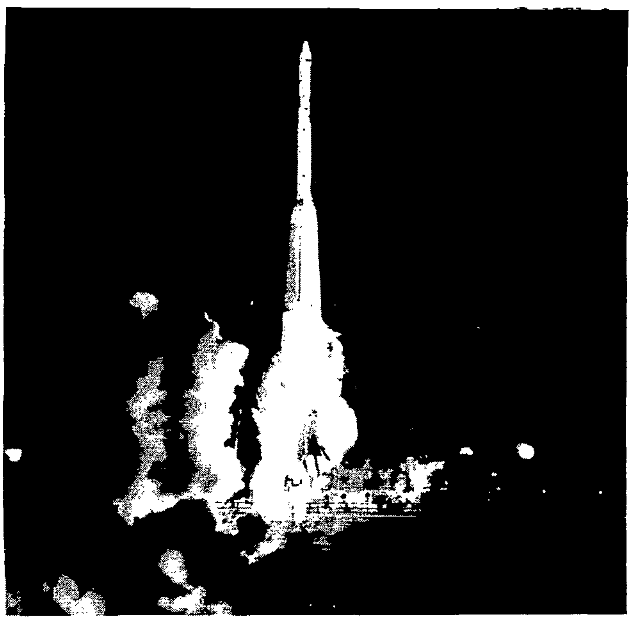


Figure 1—IMP-II launching.

Because of the third stage malfunction, the injection velocity was 1.8 percent below nominal, and an apogee of only 51,600 n.m. (nominal was 110,000 n.m.) was achieved. In addition, the dynamic perturbations introduced by the malfunction caused a shift of the spacecraft spin axis of about 78 degrees resulting in a wider range of incident sun angles which in turn resulted in low power output from the solar paddles and overheating of the spacecraft battery.

Orbit injection occurred at 0351:29.5 UT 4 October 1964 and at approximately 23.3 degrees north latitude and 66.7 degrees west longitude from an initial azimuth of 108 degrees out of Pad 17A, Cape Kennedy, Florida. Injection altitude was 197 km, and velocity at injection was 35,023 ft/sec.

The launch phase sequence of events occurred as planned (Table 1). Spacecraft telemetry data, relayed from Ascension Island, confirmed, in real-time, solar paddle erection and spacecraft separation from the third stage.

*"Delta 26, Final Report," Goddard Launch Operations Division, GSFC, GLOR-137.

Table 1

Flight Sequence of Events* Delta 26, IMP-II 3 October 1964

Event	Seconds From Liftoff	
	Nominal	Actual
Liftoff	2245:00 EST	2245:00.4 EST
MECO (Main Engine Cutoff)	148.56	144.59
Stage II Ignition	152.56	148.60
Fairing Ejection	182.56	180.05
SECO (Sustainer Engine Cutoff)	325.63	322.81
Spin-Up	361.56	357.60
Separation	363.56	359.60
Stage III Ignition	367.56	363.1†
Stage III Burnout	390.16	388.7†
Erect Solar Paddles	451.6	-
Erect Flux Gate Booms	453.6	-
Separation	458.6	-
Fire Stage III Tumble Rockets	462	-

*Reference 4.
†Based on Doppler data.

THIRD STAGE PERFORMANCE

Following the failure of Delta 26 to inject IMP-II into the desired orbit, thorough analyses of the launch data were made. The results are documented in References 4 and 5 respectively.

The nominal, predicted, and actual parameters at third stage burnout (Reference 4) are given in Table 2.

The effective velocity increment imparted by the third stage was five to six percent below nominal, which caused the total injection velocity to be about 1.8 percent low. For an IMP mission (i.e., high orbit eccentricity), a small change in injection velocity causes a large change in apogee height (Figure 2).

Table 2

IMP-II Parameters

	Nominal Detailed Test Objective (DTO)	Predicted (BTL)*	Actual
Apogee (n.m.)	110,000	122,457	51,600
Period (min)	5,915	6,883	2,097
Velocity (ft/sec)	35,591	35,656	35,023**
Stage III Velocity (ft/sec)	10,708	10,708	10,081**

*Based on actual position and velocity at third stage ignition plus nominal third stage performance, Bell Telephone Labs.
**Reconstructed from orbital elements.

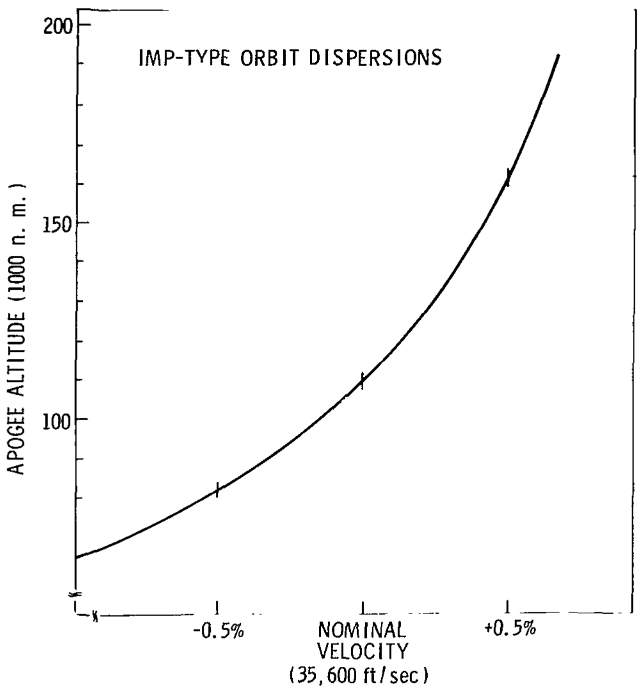


Figure 2—Apogee altitude versus injection velocity.

The difference in the velocity increment noted above was due to reduced performance and thrust misalignment occurring about 17 seconds after ignition. Tracking data indicated a decrease in acceleration after 16 seconds of normal burning until burnout, which was two seconds longer than predicted. At burnout, automatic gain control (AGC) data indicated that the third stage and spacecraft were coning (Reference 5).

The decrease of acceleration (or thrust) and the longer burn time suggest a decrease of chamber pressure. This, combined with the observed coning motion and some ground test data, leads to the hypothesis that a portion of the igniter assembly broke under the stresses of acceleration and vibration and was ejected through the throat causing an asymmetrical increase in throat area (Reference 5).

ORBIT

The IMP-II spacecraft was launched with the line of apsides extending toward the sun, but inclined about -20 degrees to the ecliptic. The initial orbit parameters and those occurring at selected times after launch are shown in Table 3.

The time of launch was selected to provide, among other things, an increasing perigean altitude. After six months in orbit, perigee had climbed from about 200 km at injection to over 1000 km. The orbit lifetime has been calculated (December, 1964) to be slightly more than 25 months with re-entry predicted during mid-November, 1966.

ATTITUDE AND SPIN RATE

The orientation of the spacecraft spin axis, actual and nominal, is given in Table 4*. The spacecraft spin axis in inertial space is parallel to a line drawn from the point specified (actual) through the center of the earth. The included angle between the measured value and the nominal value was 78.2 degrees and represents the total angular displacement of the spin axis

*GSFC memo from E. J. Pyle, "IMP-B Spin Axis Orientation," 6 November 1964.

Table 3

IMP-II Orbital Elements at Selected Times After Launch

Date	9/29/64	10/4/64	10/4/64	10/23/64	11/15/64	11/28/64	1/4/65	3/6/65	4/4/65	7/4/65	9/4/65	10/3/65	4/4/66	10/3/66
Days After Launch	Nominal	0	0	19	42	55	92	153	6 months	9 months	11 months	1 year	1 1/2 years	2 years
Apogee														
Kilometers	205,000	95,400	95,569	94,829	94,637	94,528	94,288	94,208	94,016	93,575	93,616	93,645	93,930	94,754
Nautical Miles	110,010	51,600	51,607	51,208	51,106	51,046	50,917	50,873	50,771	50,533	50,549	50,568	50,722	51,165
Perigee														
Kilometers	194	193	196.7	361.6	557.4	665.8	916.7	979.8	1081.3	1518.1	1497.9	1465.1	1156.6	333.8
Nautical Miles	104.6	104	106.2	195	301	360	495	529	585	820	809	791	624	206
Period														
Minutes	5915	2097	2096.4	2079.8	2079.9	2079.9	2080.2	2079.7	2077.1	2077.0	2077.5	2077.5	2076.8	2076.8
Hours	98.6	34.95	34.94	34.66	34.66	34.66	34.67	34.66	34.62	34.62	34.62	34.62	34.61	34.61
Inclination (deg.)	33.0	33.5	33.53	33.76	33.85	33.82	33.72	35.03	35.47	34.96	35.76	36.04	35.71	33.79
Eccentricity	.939	.88	.88	.875	.872	.869	.865	.864	.862	.854	.854	.855	.860	.875
Date Computed	Aug. 1964	10/4/64	10/5/64	11/16/64	11/30/64	12/07/64	1/25/65	3/22/65	12/23/64	12/23/64	12/23/64	12/23/64	12/23/64	12/23/64
Source	DTO	QUICK LOOK REPORT	*	*	*	*	*	*	**	**	**	**	**	**

NOTE: Re-entry into earth's atmosphere predicted for 11 November 1966.

SOURCES: *GSFC Operational Control Reports

**IMP-B Lifetime Study, pertape, 23 December 1964.

Table 4

IMP-II Spin Axis Orientation

	Nominal (degrees)	Actual (degrees)
Right Ascension	37.0	41.4
Declination	-30.7	47.4
Date	--	7 October 1964

from nominal. The effect of this attitude perturbation was to decrease the angle between the spin axis and the ecliptic plane. Hence, the range of spin axis-sun angles was extended beyond nominal limits.

The spacecraft entered sunlight approximately twenty minutes after liftoff. The initial optical aspect data indicated that the spacecraft was coning with the spin axis-sun angle varying from about 125 to 130 degrees. The observed spin rate was 14.58 rpm at T + 21 minutes. The nominal orbital spin rate should have been 23 rpm assuming an initial spin-up of 80 rpm and normal erection of appendages. The fact that the spacecraft achieved an initial orbital spin rate of 14.58 rpm has not been explained satisfactorily.

Following separation of the spacecraft from the third stage, the coning motion of the spacecraft damped out and the observed spin rate decreased to 14.25 rpm (four and one-half days after launch). The spin rate subsequently increased due to solar radiation pressure when the incident sunlight was below the spacecraft equator and decreased when the sun was above the equator (Figure 3). The spin axis-sun angle (Figure 3) was about 130 degrees some eight hours after launch (nominal was 105 degrees) and progressing further from the spacecraft equator, ultimately reaching a maximum value of 147 degrees (nominal for the specified launch time was 135 degrees).

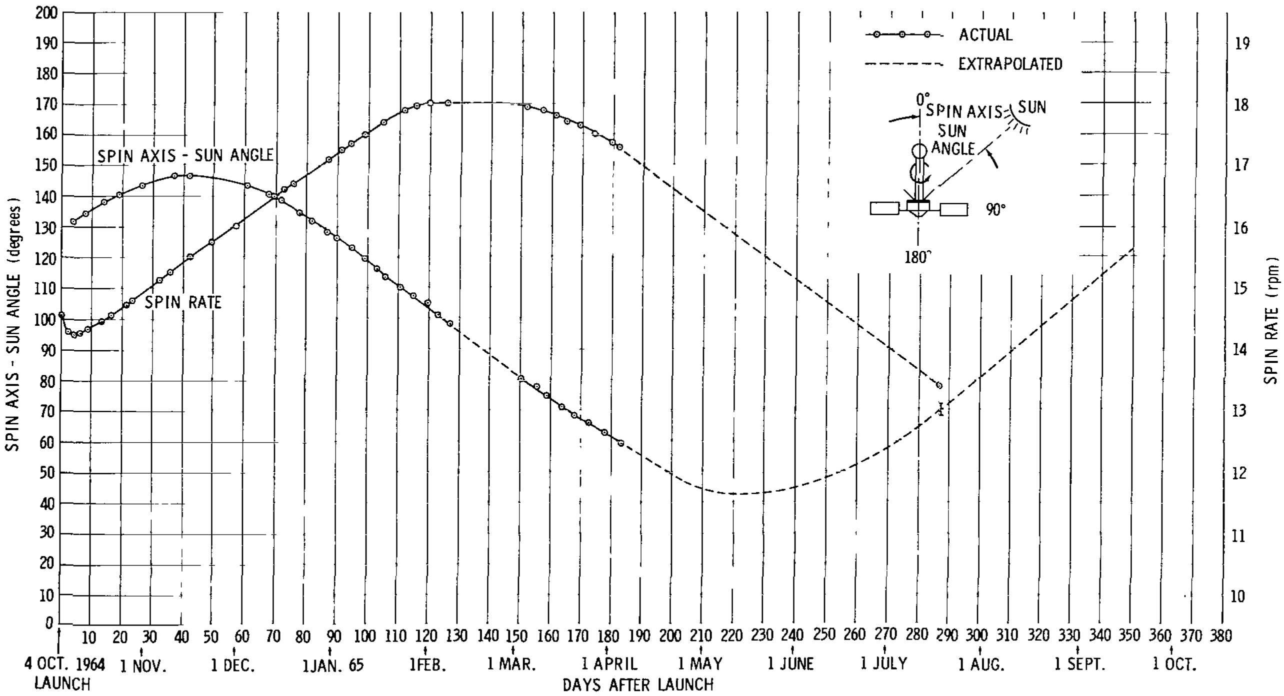


Figure 3—Spin axis-sun angle and spin rate versus time.

SPACECRAFT PERFORMANCE

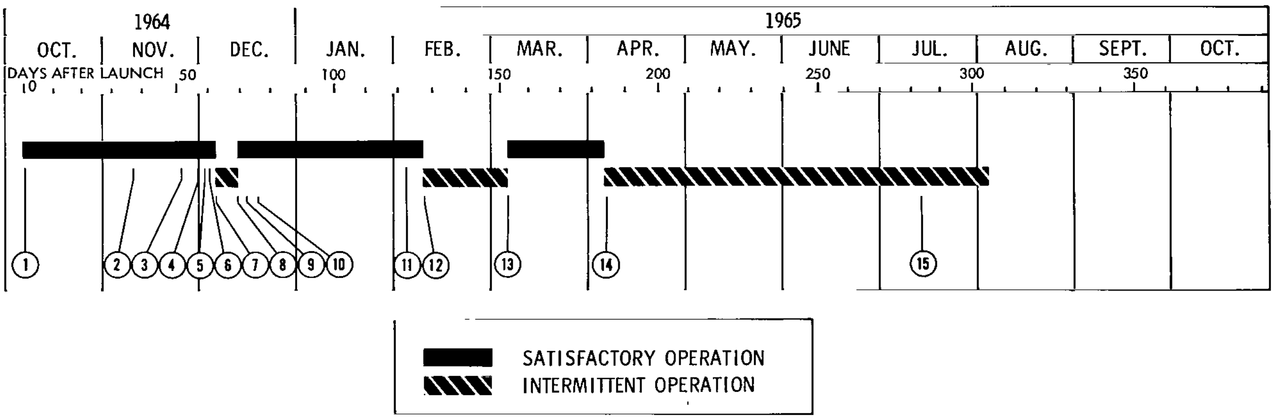
Notwithstanding the "Mission Failure" label applied to IMP-II because of the insufficient apogee altitude, the spacecraft did, in fact, provide useful data during its travels within the magnetosphere. While its apogee altitude was only half of its immediate predecessor IMP-I, it exceeded and equaled respectively, the altitude of its forerunners, Explorers XII and XIV.

In addition to a low apogee, the launch malfunction indirectly caused the failure of the spacecraft battery. Symptoms of the failure began to appear some 57 days after launch as the battery proved incapable of sustaining spacecraft operation within the shadow of the earth. By 63 days after launch, the battery had failed completely (but in a fail safe mode). Thereafter, the spacecraft would operate (Figure 4 and Appendix A) only during periods of favorable incident sun angles. However, each time the spacecraft entered a shadow, it would turn off for the (nominal) 8-hour recycle period.

Under these conditions, the spacecraft transmitted 56 days of data during the 59-day period beginning 12 December and ending 9 February 1965, and 28 days of data during the 32-day period beginning 5 March and ending 5 April 1965.

During a third period of favorable sun angles (July, 1965) significant quantities of data were not obtained. The reason for this is not known at this writing, but decreased paddle output due to radiation damage is a possibility.

Throughout the periods of operation (approximately five months) all experiments and spacecraft systems performed satisfactorily. No failures have been reported by any experimenters although all data have not yet been analyzed.



NOTES:

(1) 4 OCTOBER 1964 - LAUNCH (EXPLORER XXI, DELTA 26).

(2)&(3) UNDER-VOLTAGE TURN-OFFS DUE TO POOR SUN-ANGLE.

(4)–(6) UNDER - VOLTAGE TURN - OFFS WHILE IN EARTH'S SHADOW.

(7) 5 DECEMBER THRU 12 DECEMBER - INTERMITTENT OPERATION DUE TO FAILURE OF S/C BATTERY CAUSED BY EXCESSIVE TEMPERATURE.

(8) 13 DECEMBER - SATISFACTORY OPERATION RESUMED AS SUN-ANGLE REACHED A FAVORABLE POSITION.

(9) 13 - 18 DECEMBER - UNDER - VOLTAGE TURN OFFS (4) EACH TIME THE S/C ENTERED THE EARTH'S SHADOW AT PERIGEE.

(10) 18 DECEMBER - S/C ENTERS 100% SUNLIGHT ORBIT.

(11) 4 FEBRUARY 1965 - S/C TELEMETRY SPURIOUSLY COMMANDED OFF; 23 1/2 HOURS OF DATA LOST BEFORE TELEMETRY WAS COMMANDED ON.

(12) 9 FEBRUARY - INTERMITTENT OPERATION RESUMED AS SUN - ANGLE BECAME UNFAVORABLE; DURATION OF "ON" PERIODS WERE LESS THAN 5 MINUTES UNTIL 3 MARCH.

(13) 5 MARCH - SAME AS (8) ABOVE.

(14) 5 APRIL - INTERMITTENT OPERATION RESUMED AS SUN - ANGLE BECAME UNFAVORABLE.

(15) MID - JULY - SOME PERIODS OF OPERATION AS LONG AS 1/2 HOUR.

Figure 4—IMP-II status of operation.

On 4 and 5 February 1965, the spacecraft signal was lost for 23-1/2 hours. It was determined that the transmitter had been commanded-off by an unknown source. Fortunately, reactivation occurred by command from Canarvon* about one-half hour prior to the commencement of a solar storm. The spacecraft transmitted continuous data throughout the storm period before resuming intermittent operation several days later, due to unfavorable incident sun angles.

Several off periods which occurred in early April are suspected to be caused by similar circumstances, but it has not been possible to determine the origin of the off commands. On-board problems or response due to commands intended for other spacecraft are possibilities.

Because of the failure of the spacecraft battery, the undervoltage-recycle programmer function operated properly for some 420 cycles as of 1 August 1965. The recycle time, a nominal 8 hours, proved to be quite consistent at about 7 1/4 hours.

PERFORMANCE PARAMETER IN-FLIGHT DATA

One of the 16 frames of the telemetry format is allocated to the measurement of fifteen analog performance parameters (PP). Included are the measurement of four voltages, three currents, seven temperatures, and one calibration point. About thirty measurements of each parameter are made in one hour of operation.

Voltages Measured

PP1 system voltage (19.6 volts, normally)
PP2 prime converter + 50 volts ±1%, regulated output
PP8 prime converter + 12 volts ±1%, regulated output
PP12 multi-converter + 7 volts ±1%, regulated output

Currents Measured

PP3 battery charge current
PP4 spacecraft current (1.9 amps)
PP9 solar paddle output current

Temperatures Measured

PP5 center tube
PP6 Rb gas cell
PP7 battery
PP10 solar paddle

*The tracking stations were unaware of IMP-II's off-on command capability since this was designed to be used only in the termination of the spacecraft mission. Accordingly, they did not know that a normal range and range rate interrogation would reactivate the spacecraft transmitter. In this case, Canarvon issued a range and range rate command on schedule, despite the fact that they had been unable to acquire the spacecraft signal as it came over the horizon. They reported, with some surprise, that they acquired the spacecraft telemetry immediately upon issuing the range and range rate command.

Temperatures Measured (cont'd)

PP13 Rb lamp
PP14 prime converter
PP15 transmitter

The location of the voltage and current sensors is shown relative to the IMP electrical system in Figure 5. The placement of the thermistors is shown in Figure 6.

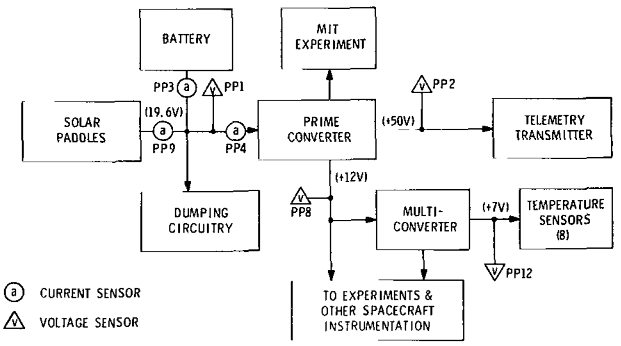


Figure 5—IMP-II electrical performance parameters.

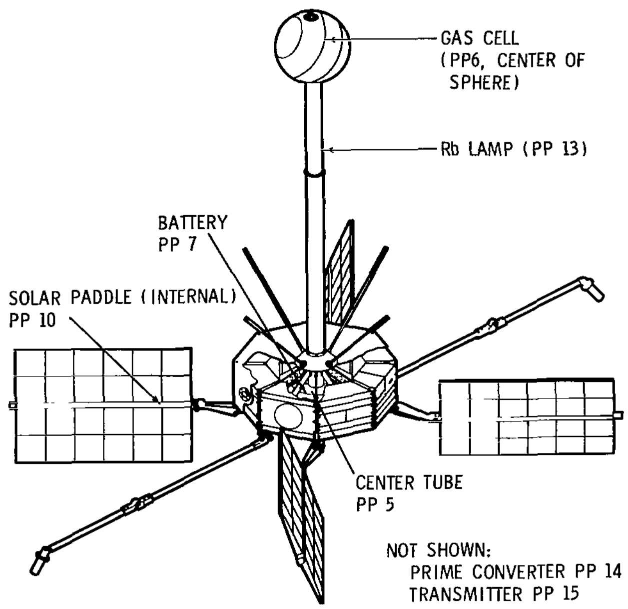


Figure 6—IMP-II placement of thermistors.

From analysis of the IMP-II PP data, as well as IMP-I (Reference 1) and ground test data on IMP-type analog oscillators, it is apparent that the PP data drift following launch, reaching an error of about 2 or 3 percent after a month or two of operation. The telemetered data in Appendix B have been analyzed and an appropriate correction factor assigned. The resulting adjusted data are shown in Appendix C. It is estimated that the accuracy of the observed or telemetered data is ±3 percent (frequency basis) and the adjusted data ±1 percent.

In-Flight Temperatures

During the periods of operation, most of the temperatures within the octagonal instrument compartment remained in the region of +10* to +60 °C (Figures 7 and 8). The transmitter (typically a hot location) reached a maximum temperature of +58° C about two months after launch; the battery reached +50° C at about the same time, and the prime converter reached a maximum of +39° C some six months after launch.

*Data mentioned herein are the adjusted data, i.e., they include a correction factor for calibration drift.

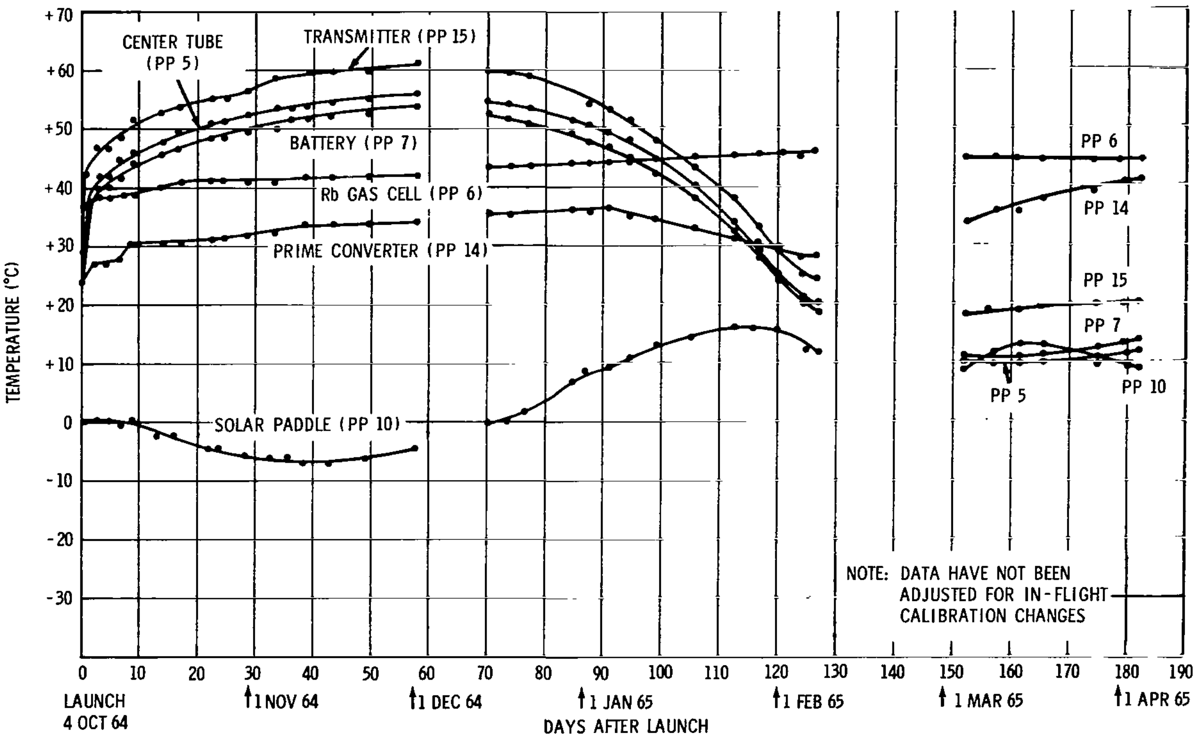


Figure 7—IMP-II temperature data (not adjusted).

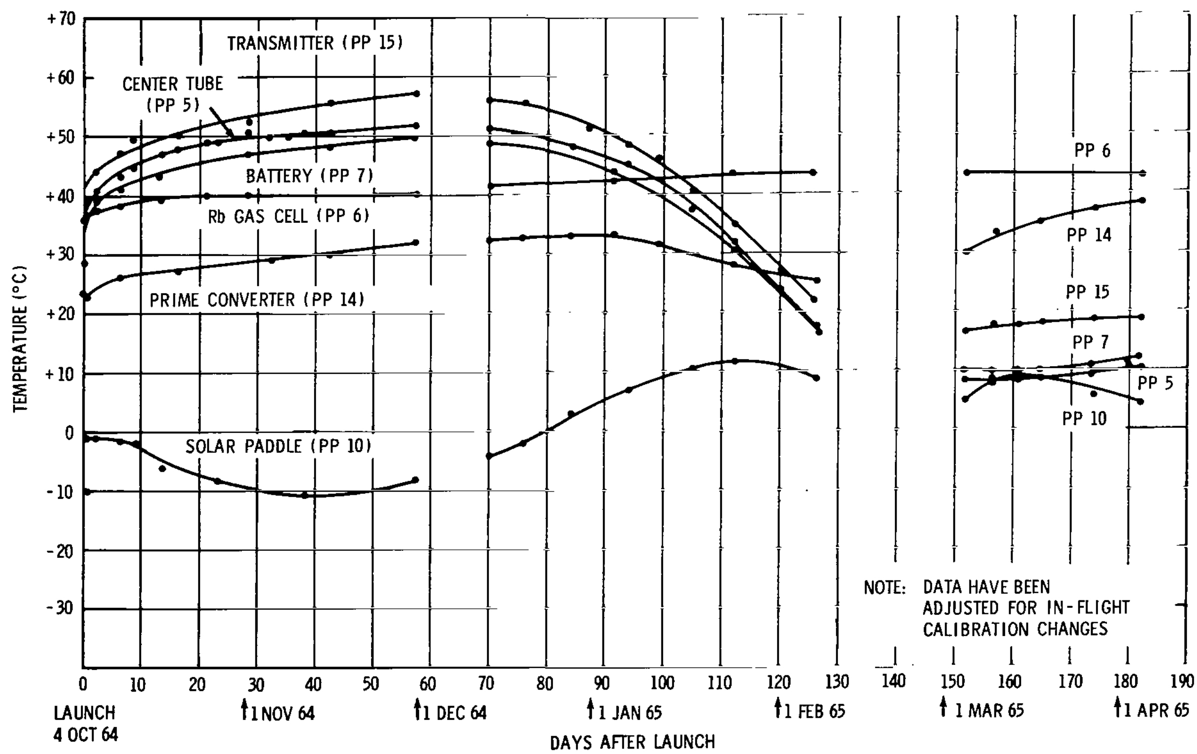


Figure 8—IMP-II temperature data (adjusted).

Two critical components of the Rb vapor magnetometer have active thermal control circuits (resistance heater). The temperature of the Rb gas cell remained within a satisfactory range of +35 to +45°C during all operational periods while the Rb lamp was satisfactorily maintained between 115 and 120°C.

For purposes of comparison, the predicted and actual (adjusted) temperature data for the battery, prime converter, and transmitter locations are shown in Figures 9, 10, and 11 respectively. In general, the in-flight temperatures exceeded predictions when the sun was shining from below the spacecraft equator (90 degrees to spin axis), while at angles above the equator the actual temperatures were equal to or less than predictions.

Power System Data

The solar paddle output current and the spacecraft load current are shown as a function of days after launch in Figures 12 and 13. The average steady state spacecraft load remained at 37.0 watts throughout the spacecraft lifetime. (The MIT experiment causes a transient of a few milliseconds duration to 50 watts twice in every 82 seconds, and a relatively constant ten-second power drain to as high as 42 watts once in every 82 seconds (neither transient nor ten-second load are telemetered). It is this increase that accounts for the fact that, following the failure of the battery, the spacecraft would not operate continuously, even though the solar paddle output exceeded the steady state spacecraft power requirement. For continuous operation it is necessary for the solar paddles to produce enough power to supply the additional MIT load above the steady state requirement.)

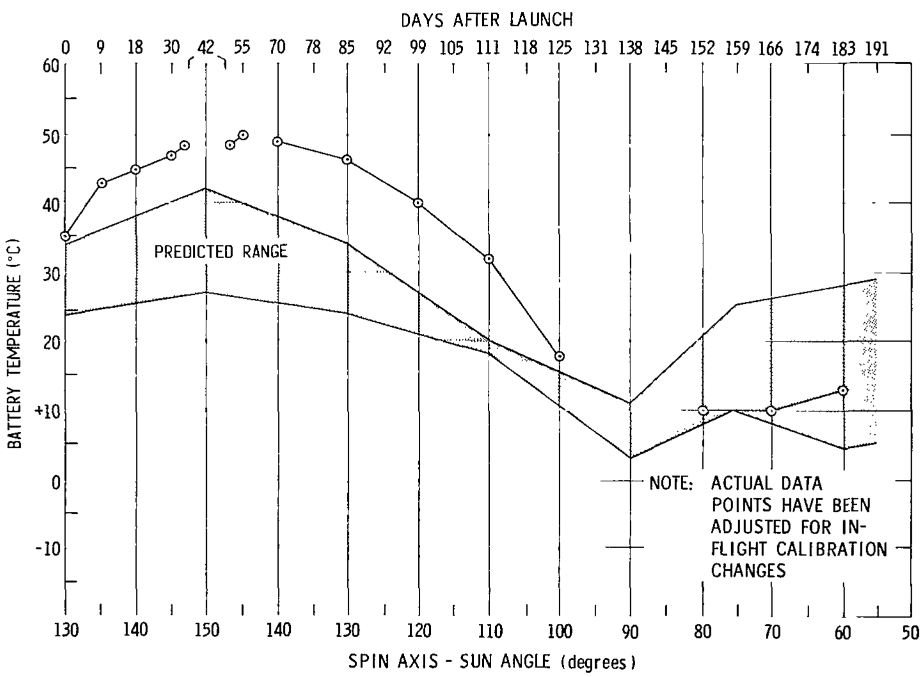


Figure 9—IMP-II battery temperature.

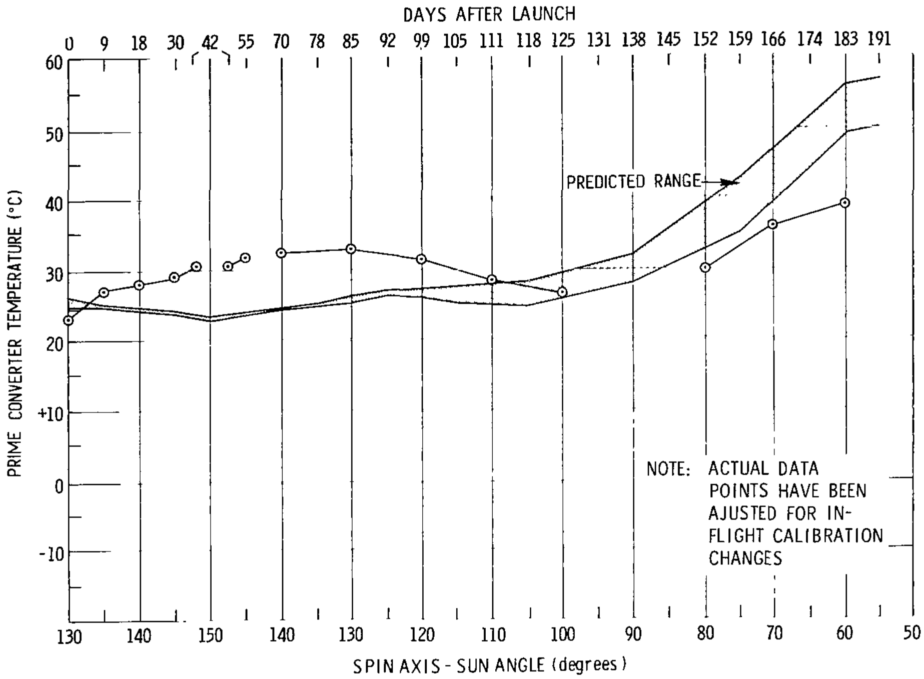


Figure 10—IMP-II prime converter temperature.

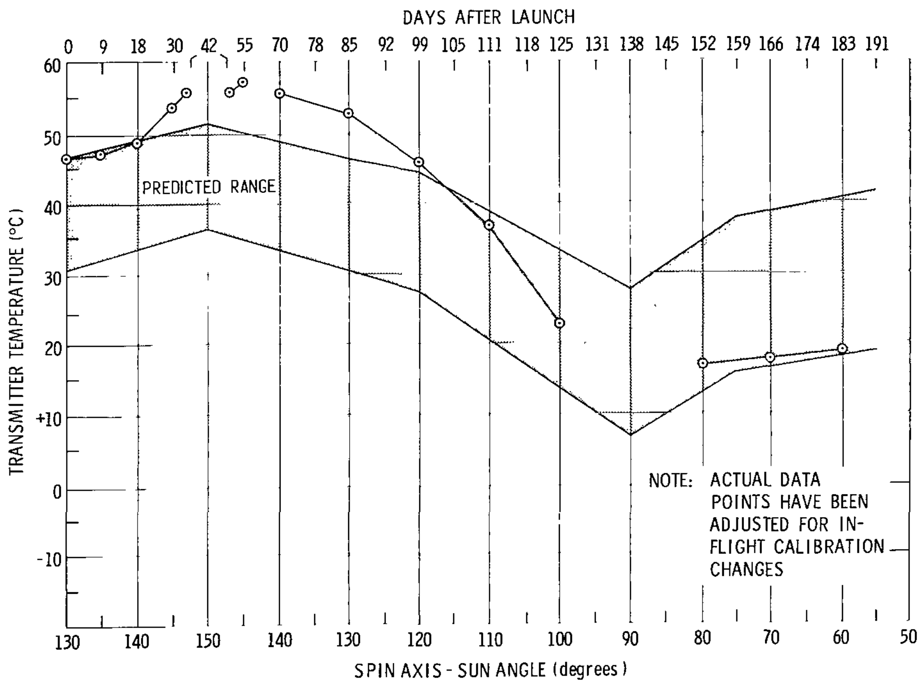


Figure 11—IMP-II transmitter temperature.

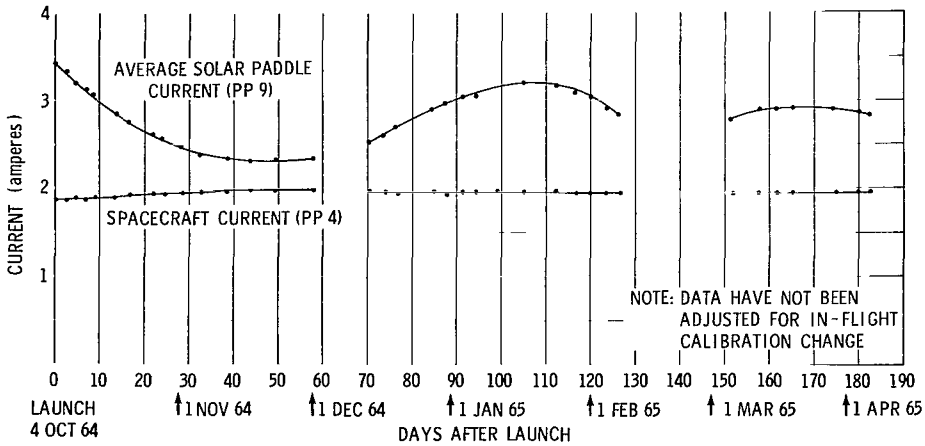


Figure 12—IMP-II current data (not adjusted).

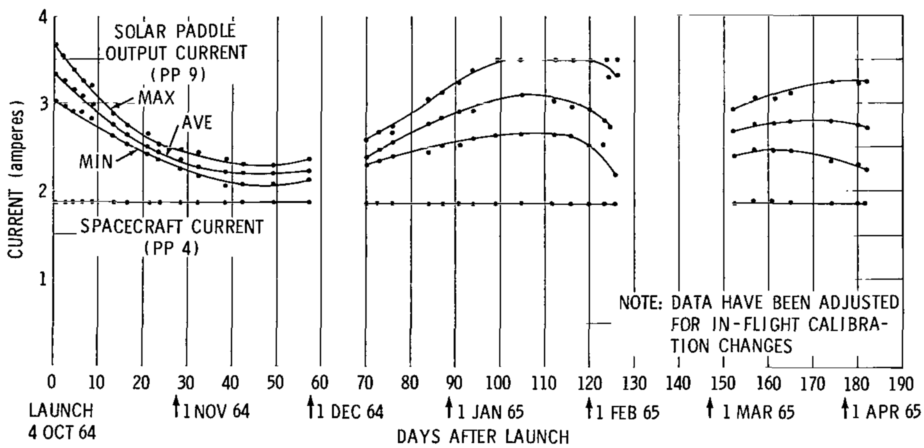


Figure 13—IMP-II current data (adjusted).

The solar paddles produced an average of 65.8 watts initially, a low of 43.5 watts six weeks after launch, and 61.5 watts 3 1/2 months after launch (Figures 14 and 15). Degradation of power output amounted to about 16 percent after three months in orbit. The variation of paddle output as the satellite spins is shown in Figure 13. For example, at spin axis-sun angles of 140 to 150 degrees, the variation from lowest output to highest was 2 1/2 watts. At sun angles of about 100 to 110 degrees, the variation during a spin revolution was over 16.5 watts. The telemetered (Figure 16) and adjusted (Figure 17) data of the regulated outputs of the prime and multi-converters indicates that these voltages remained within the specified tolerances of ±1 percent.

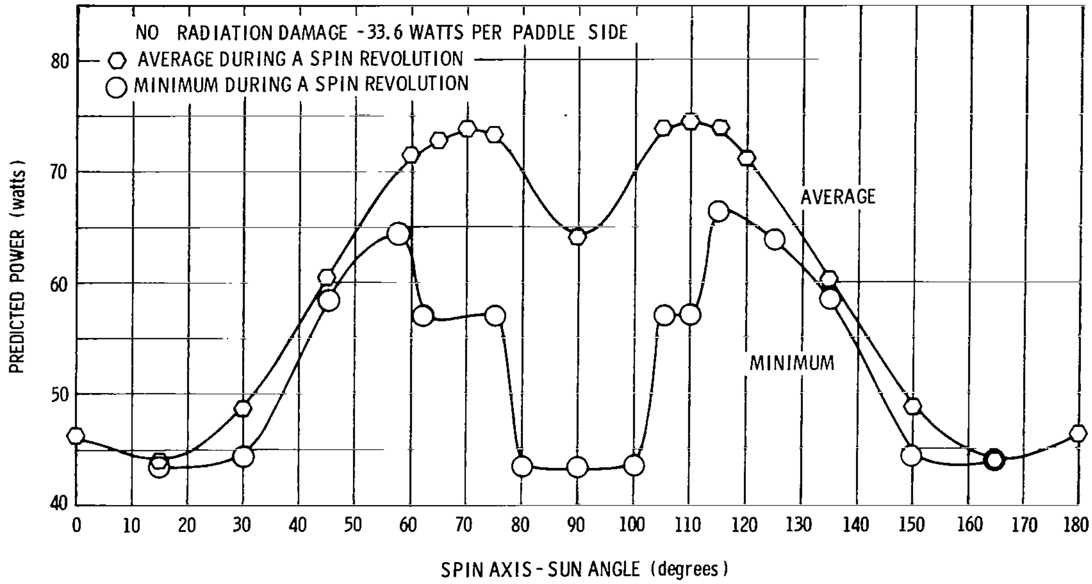


Figure 14—IMP-II predicted power.

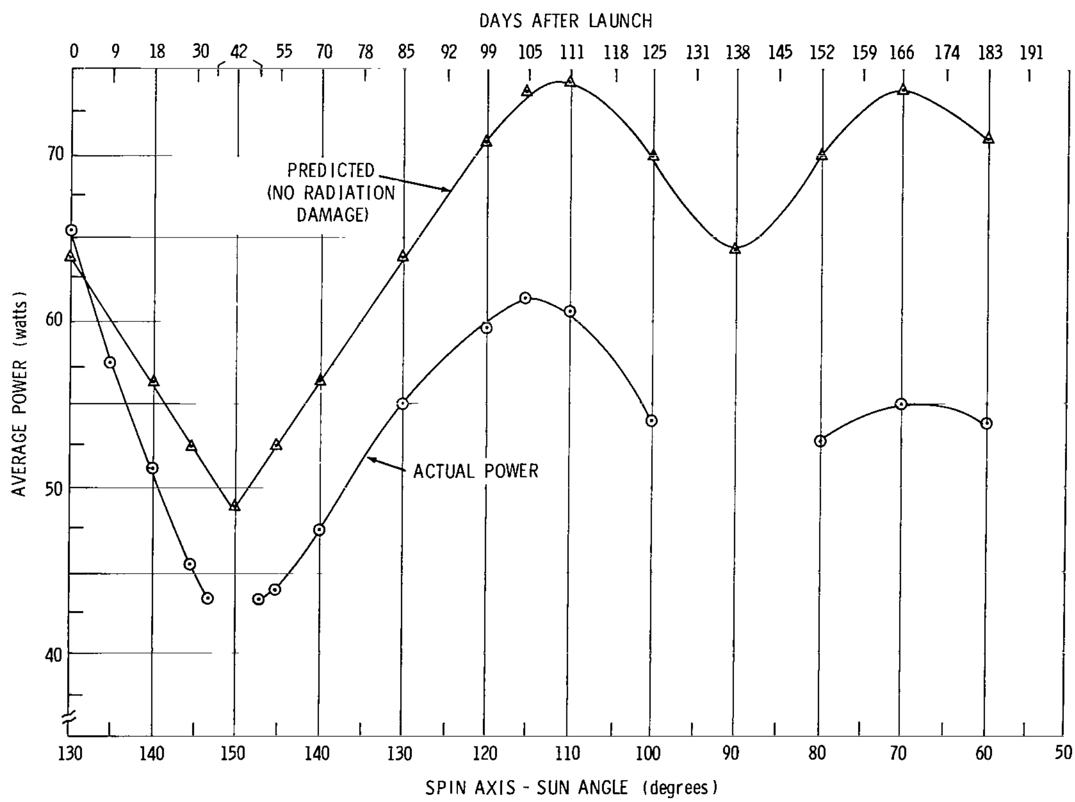


Figure 15—IMP-II comparing average with predicted power.

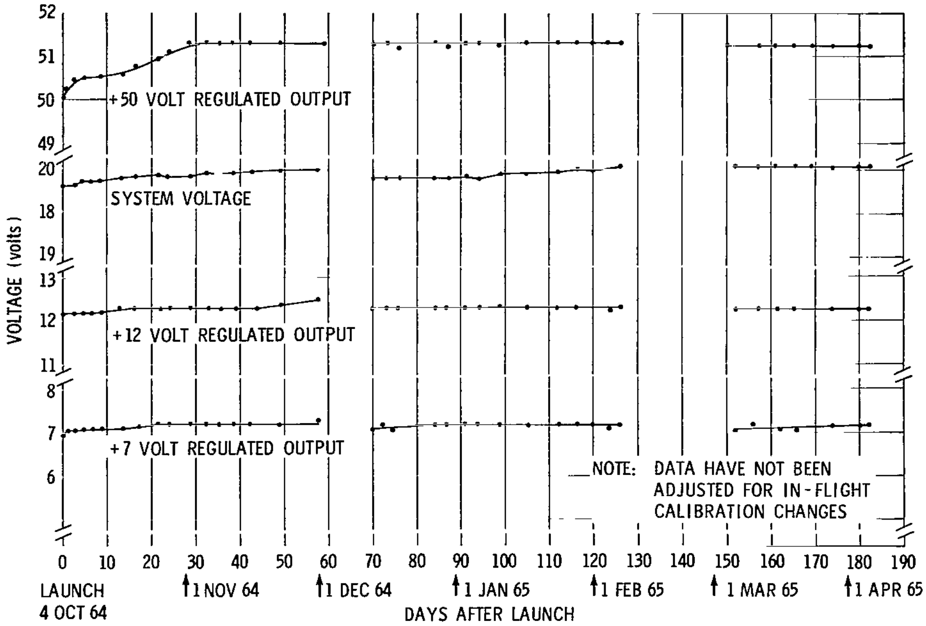


Figure 16—IMP-II voltage data (not adjusted).

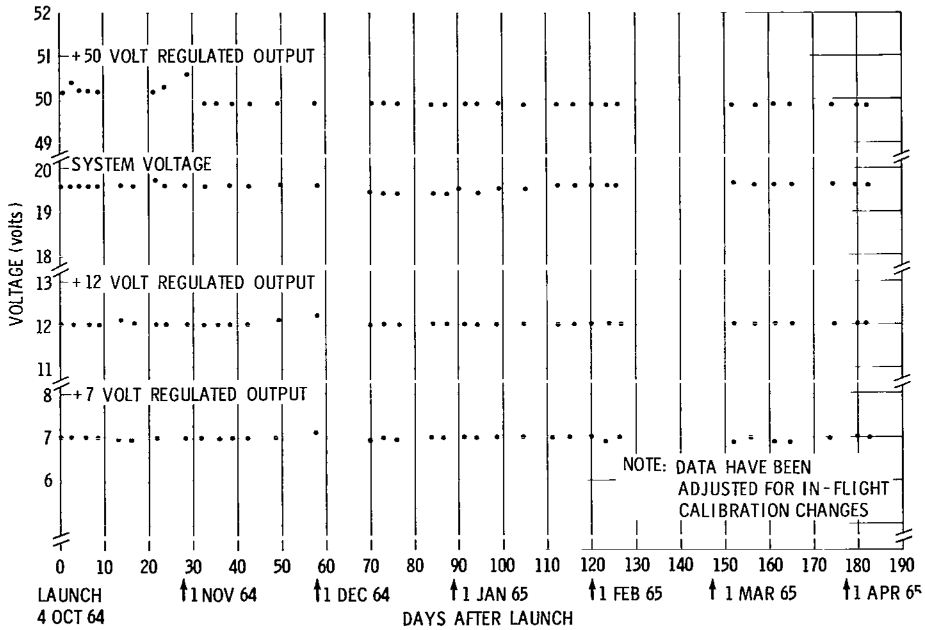


Figure 17—IMP-II voltage data (adjusted).

BATTERY PROBLEM

The battery in IMP-II failed as a result of the excessive temperature environment to which it was subjected. There were two factors identified as causes of this unsuitable battery temperature (+55°C at 55 days after launch).

1. The tip-off or perturbation of the spin axis incurred during the launch phase caused the spin axis-sun angle to progress to about 147 degrees, or about 12 degrees beyond the nominal limit. This region is the warmest for the battery.

2. Although sun angles over 135 degrees were beyond the nominal limit for the launch trajectory and time, the thermal control design limit for IMP was set at 150 degrees. The thermal control failed to maintain the in-flight temperature of the battery within design limits at angles over 130 degrees.

It is an established fact that silver cadmium batteries of the type used on IMP exhibit a drastic reduction of lifetime when subjected to temperatures in excess of +35°C.* Tests have shown that, compared to lifetimes at +25°C, silver cadmium cells last only 70 percent as long at +35°C and only 20 percent as long at +50°C. The design of the cells employs a multi-layer cellophane membrane as a separator between the silver and cadmium electrodes. During the life of a cell, the silver reacts with the cellophane, layer by layer. This reaction is fairly slow at room conditions but is accelerated at higher temperatures. When the separator of a cell fails, a short circuit results, thereby impressing a higher than normal charge voltage on the remaining cells of the battery. Gas evolution begins to cause increasing internal pressure within the good cells, ultimately resulting in a cell case rupture and electrolyte leakage. Even at this point, a battery might be able to operate partially depending upon the amperage demands of the load. However, when all of the electrolyte outgasses from the leaky cell, an open circuit exists and the battery is thereafter incapable of supplying any current.†

In the case of IMP-II, battery performance appeared to be satisfactory until the spacecraft entered a perigee shadow (Appendix D) on 30 November. The spacecraft immediately turned off. However, on the preceding orbit, the battery operated the spacecraft through a shadow period of 20 minutes duration. It is concluded, in the failure mode hypothesis, that a failure of a cell separator occurred between 1200 UT, 20 November and 2200 UT, 30 November 1964—approximately 1400 hours after launch.

At this time, the output of the solar paddles was marginal due to the incident sun angle, and as the satellite spun, the output periodically fell below the needs of the spacecraft. Because the deficiency was small, perhaps 100 to 200 milliamperes, the twelve good cells were able to supply this need. However, as the spacecraft entered the earth's shadow, the entire spacecraft load (2.8 amperes) was transferred rapidly to the battery. With only twelve good cells it seems likely

*Private communication with T. Hennigan and K. O. Sizemore, GSFC, December 1964.
†Private communication, K. O. Sizemore, GSFC, July 1965.

that the battery voltage dropped below the 12.0 volt threshold of under-voltage turnoff and caused the spacecraft power to shut down for eight hours.

Meanwhile, the twelve good cells were subjected to the 19.6 volt charging voltage. If all cells were exactly balanced, each would have 1.63 volts impressed across its terminals. Since exact equality among all cells is not a characteristic of a typical silver cadmium battery, especially after two months in orbit, it is reasonable to assume that some cells would have less and some more than 1.63 volts across their terminals. Gas evolution begins at 1.64 volts per cell and it therefore is suspected that some cells were producing internal gas pressure build-ups and leakage of electrolyte at this time.

On 3 December, the spacecraft entered a short (less than two to three minutes) shadow of the moon which was preceded and followed by about 30 minutes of penumbra.* The spacecraft continued to operate through this period. The traversal of the penumbra caused the gradual decrease of solar output power and the gradual transfer of the load to the battery. Under these conditions and despite the shorted cell, the battery was able to supply the power demand without having the primary system voltage drop below the turnoff point (12 volts). The spacecraft continued to turn off each time it entered the earth's shadow, once each orbit.

On 5 December 1964 at about 1400 UT, the spacecraft turned off while in sunlight. This, according to the hypothesis, marks the complete failure of the battery, that is, an open circuit caused by the absence of electrolyte in a cell.

Thereafter, the battery was totally incapable of supplying any current whatsoever. The spacecraft could and did operate at times when the solar paddles were able to supply all of the power needed. If the sun angle was such that the paddle output would periodically dip below the requirement of the spacecraft, as the satellite spun turnoff would occur immediately.

One further piece of data further substantiates this failure hypothesis. Since the recycle timers receive power from a regulator whose input is the solar paddle and/or battery voltage, the timers would NOT operate, after a turnoff, for any periods spent in the shadow of the earth, unless the battery was capable of supplying current. In other words, if the battery had failed and the satellite was in darkness, the timers would receive no electrical power. This being the case, one would expect that the recycle times would be extended when a turnoff occurred due to a shadow compared to a no-shadow case. On orbits 126 through 131 occurring from 5 April through 12 April 1965, apogee shadows of from 2 1/2 to 4 1/2 hours were traversed by the satellite. The loss of signal periods for these orbits averaged about 12 hours in duration, instead of the previously dependable 7 1/2 $\pm$ 1/4 hours. This confirms the supposition that the battery was not capable of supplying any current whatsoever.

*Region of partial illumination.

CONCLUDING REMARKS

The IMP-II spacecraft, the second in the continuing series of IMP satellites, was not injected into an acceptable orbit and hence could not accomplish the primary mission objectives of studying the interplanetary medium.

The lowered apogee of only 51,600 n.m. or about one-half of the desired altitude was attributed to a malfunction of the third stage solid propellant motor of the Delta 26 launch vehicle. Therefore the IMP-II launch was subsequently categorized as a mission failure.

The spacecraft operated satisfactorily for nearly five of its first six months in space. The nine scientific experiments operated properly and most of the secondary objectives were attained as well as the accumulation of significant data within the magnetosphere.

Operation of the spacecraft after two months in orbit was marred by the failure of the silver cadmium battery which was a direct result of excessive temperature caused by the attitude perturbation introduced by the launch malfunction and the inability of the passive thermal control to maintain the battery within its design limits. The thermal design and battery charging techniques were modified for follow-on IMPs to preclude the problems encountered during the IMP-II flight.

(Manuscript received October 1, 1965)

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Appendix A

IMP-II Spacecraft Operational Periods

Item	Spacecraft On							Spacecraft Off		Remarks
	From		To		Duration			Duration		Spacecraft Off Periods Represent Undervoltages (~7 1/4 hrs) and/or Other Loss of Signal Causes
	Date	Time	Date	Time	Days	Hours	Min.	Hours	Min.	All Dates and Times are Universal Time (UT)
1.	10/4/64	0345	11/10/64	1720 ±15	37	13	35 ±15	7	25 ±15	The spacecraft was activated 40 minutes prior
2.	11/11	0043	11/25	0418	14	3	55	7	26	to launch
3.	11/25	1144	11/30	2248 ±6	5	11	04 ±6	7	18 ±6	
4.	12/1	0606	12/2	0930 ±28	1	3	24 ±28	7	17 ±28	
5.	12/2	1647	12/3	2011 ±7	1	3	24 ±7	7	16 ±7	
6.	12/4	0327	12/5	0642	1	3	15	7	17*	
7.	12/5	1359*	12/5	1434*	—	—	35	7	17*	
8.	12/5	2151	12/5	2251	—	1	00	7	21	
9.	12/6	0612	12/6	0642	—	—	30	7	25	
10.	12/6	1407	12/6	1414	—	—	07	7	33	
11.	12/6	2147	12/6	2209	—	—	22	7	42	
12.	12/7	0551	12/7	0553	—	—	02	0	20?	
13.	12/7	0613	12/7	0614	—	—	01	?		
14.	12/7	?	12/7	?		?		?		
15.	12/7	2123	12/7	2205	—	—	42	7	21	
16.	12/8	0526	12/8	0600	—	—	34	7	14	
17.	12/8	1314	12/8	1328	—	—	14	7	24	
18.	12/8	2052	12/8	2155	—	1	03	7	23	
19.	12/9	0518	12/9	0648	—	1	30	7	25	
20.	12/9	1413	12/9	1435 ±7	—	—	22 ±17	7	37 ±17	
21.	12/9	2212	12/9	2220	—	—	08	7	12*	
22.	12/10	0532*	12/10	0634*	—	1	02?	7	12*	
23.	12/10	1343	12/10	1633	—	2	50	7	16	
24.	12/10	2349	12/11	0125 ±4	—	1	33	8	29	
25.	12/11	0954	12/11	1027	—	—	33	7	17	
26.	12/11	1814	12/11	1906	—	—	52	7	24	
27.	12/12	0230	12/12	0327	—	—	57	7	28	
28.	12/12	1055	12/12	1154 ±15	—	—	59 ±15	7	35 ±15	
29.	12/12	1929	12/13	2246 ±9	—	27	17 ±9	7	23 ±9	
30.	12/14	0609	12/15	0852	—	26	41	7	58	
31.	12/15	1650	12/16	2035 ±35	—	27	45 ±35	8	35	
32.	12/17	0510	12/18	0603	—	24	57	8	11?	
33.	12/18	1414	2/4/65	1749	48	3	35	23	29	Turnoff at 2/4, 1749 was not undervoltage but rather
34.	2/5/65	1718	2/9	0908	3	15	50	7	17	a command-off of the spacecraft carrier from un-
35.	2/9	1625	2/9	1629	—	—	04	7	17	known source. Carrier commanded on at 2/5, 1718.
36.	2/9	2346	2/9	2350	—	—	04	7	16	
37.	2/10	0706	2/10	0710	—	—	04	7	16	
38.	2/10	1426	2/10	1430	—	—	04			End of spacecraft "Lifetime No. 1"
	(Tracking Efforts Reduced Because of Intermittent Operation)									Negligible amounts of data were transmitted from 2/10 - 3/2/65
39.	3/3	1323	3/3	1333	—	—	10	7	16	Start of spacecraft "Lifetime No. 2"
40.	3/3	2049	3/3	2206	—	1	17	7	24*	
41.	3/4	0530*	3/4	0556	—	—	26	7	19*	
42.	3/4	1315*	3/4	1525	—	2	10	7	55	
43.	3/4	2320*	3/4	2350	—	—	30	7	20*	
44.	3/5	0710*	3/7	0257	1	19	47	7	28*	
45.	3/7	1025*	3/7	1239	—	2	14	7	21	
46.	3/7	2000*	3/23	1435	15	18	35	10	20?	Turnoff at 1434:58 during sequence 2, frame 14,
47.	3/24	0055*	3/24	0105	—	—	10	8	20?	channel 9.
48.	3/24	0925*	3/24	0932	—	—	08	10	23?	
49.	3/24	1955*	3/24	2002	—	—	07	1	13?	
50.	3/24	2115*	3/25	0052	—	3	37	1	08?	
51.	3/25	0200	4/5	0123	10	23	23	12	36	Extended recycle time due to clock stoppage while
52.	4/5	1359	4/5	1403	—	—	04	4	53	in shadow.

*Estimated
Sources: STADAN daily reports and spacecraft data.

IMP-II Spacecraft Operational Periods (Continued)

Item	Spacecraft On							Spacecraft Off		Remarks
	From		To		Duration			Duration		Spacecraft Off Periods Represent Undervoltages (~7 1/4 hrs) and/or Other Loss of Signal Causes
	Date	Time	Date	Time	Days	Hours	Min.	Hours	Min.	All Dates and Times are Universal Time (UT)
53.	4/5/65	1856	4/5/65	1932	—	—	36	7	17	LOS period ending at 1856 was an undervoltage.
54.	4/6	0249	4/6	0256	—	—	07	7	15	
55.	4/6	1011	4/6	1042	—	—	31	12	38	Same as item #51
56.	4/6	2310	4/7	0008	—	—	58	7	22	LOS period ending 2310 was an undervoltage.
57.	4/7	0730	4/7	0747	—	—	17	17	16	
58.	4/7	1503	4/7	1519	—	—	16	7	19	
59.	4/7	2238	4/7	2246	—	—	08	11	23	Same as item #51
60.	4/8	1019	4/8	1105	—	—	46	7	17	
61.	4/8	1822	4/8	1832	—	—	10	14	45	14:45 off represents two recycle periods.
62.	4/9	0917	4/9	0919	—	—	02	11	59	Same as item #51
63.	4/9	2118	4/9	2137	—	—	19	7	21	LOS period ending at 2118 was an undervoltage.
64.	4/10	0458	4/10	0459	—	—	01	7	16	
65.	4/10	1215	4/10	1220	—	—	05	7	17	
66.	4/10	1937	4/10	1943	—	—	06	19	53 ?	
67.	4/11	1536	4/11	1541	—	—	05	7	17	
68.	4/11	2258	4/11	2303	—	—	05	7	17	
69.	4/12	0620	4/12	0625	—	—	05	12	06?	
70.	4/12	1831	4/12	1839	—	—	08	14	39	14:39 off represents two recycle periods.
71.	4/13	0918	4/13	0924	—	—	06	7	16	
72.	4/13	1640	4/13	1645	—	—	05			End of spacecraft "Lifetime No. 2."
	(Tracking Efforts Reduced Because of Intermittent Operation)									Less than 10 minutes of data recorded per day from 4/14 to 7/10/65
73.	7/11	?	7/11	?	—	—	12		?	
74.	7/15	0108	7/15	0111	—	—	03	7	20	
75.	7/15	0831	7/15	0835	—	—	04	7	17	
76.	7/15	1552	7/15	1608	—	—	16	7	17	
77.	7/15	2325	7/15	2343	—	—	18	7	16	
78.	7/16	0659	7/16	0718	—	—	19	7	17	
79.	7/16	1435	7/16	1451	—	—	16	7	17	
80.	7/16	2208*	7/16	2224*	—	—	16	7	17	
81.	7/17	0546*	7/17	0557*	—	—	16	7	17	
82.	7/17	1314	7/17	1344	—	—	30	7	16	
83.	7/17	2100	7/17	2135	—	—	35	7	17	
84.	7/18	0452	7/18	0458	—	—	06	7	15	
85.	7/18	1213	7/18	1220	—	—	07	7	30	
86.	7/18	1950	7/18	2004	—	—	14			NOTE: An estimated 420 undervoltage recycles occurred as of 1 August 1965.

*Estimated
Sources: STADAN daily reports and spacecraft data.

IMP-II Spacecraft Operational Periods (Continued)

IMP-II Minutes of Data Acquired, 1965

Day	July	August	September	October
1	-	6	6	49
2	-	4	10	14
3	-	22	8	8
4	7	1	8	5
5	0	1	0	17
6	-	0	15	0
7	-	16	7	6
8	-	0	34	4
9	-	0	43	1
10	-	0	27	1
11	8	0	87	0
12	0	-	198	5
13	-	-	238	1
14	-	-	169	0
15	37	-	115	0
16	39	-	285	0
17	109	-	18	0
18	24	0	7	0
19	26	0	216	-
20	0	-	115	-
21	70	-	122	-
22	53	-	100	0
23	28	-	58	-
24	0	0	33	-
25	19	0	83	-
26	83	-	38	-
27	80	0	8	-
28	6	0	78	-
29	64	-	12	-
30	83	-	13	-
31	12	4	-	-

NOTE: A dash means no attempt to acquire data was made.
All data acquisition efforts ceased as of 1 November 1965.

Appendix B

IMP-II Performance Parameter Data

Telemetered or Observed Values (Uncorrected)

(From Quick Look Tapes)

Date	Days After Launch	Sun Angle	Spin Rate (rpm)	PP1 (volts)	PP2 (volts)	PP8 (volts)	PP12 (volts)	PP3 (ma)	PP4 (amps)	PP4 Min (amps)	PP9 Ave (amps)	PP9 Max (amps)	PP5 (°C)	PP6 (°C)	PP7 (°C)	PP10 (°C)	PP13 (°C)	PP14 (°C)	PP15 (°C)	11** (CFN)
10/4/64	T + 24 min	125-130	14.58	15.8	50.0	12.2	7.0	>600	2.27	3.09	3.42	3.78	23.6	36.3	29.4	-8	108	29.3	29.4	0
10/4	T + 8 1/2 hrs	130	14.51	19.6	50.2	12.2	7.1	33	1.88	3.09	3.42	3.78	37	37.2	35.4	+1	117	24.5	42	0
10/6	2 1/2	131	14.29	19.6	50.4	12.2	7.1	10	1.87	3.02	3.33	3.65	41.5	38	39.5	+1	118	27	46	-1/2
10/8	4 1/2	133	14.25	19.7	50.5	12.2	7.1	—	1.90	2.96	3.20	3.52	42	38	40	0.4	118	27	46.5	-1/2
10/10	6 1/2	134	14.27	19.7	50.5	12.2	7.1	10	1.90	2.96	3.15	3.40	44.3	38.7	41.8	0	118	27.8	48.9	-1
10/12	8 1/2	135	14.32	19.7	50.5	12.2	7.1	9	1.91	2.90	3.05	3.33	45.8	38.4	43.7	+1/2	118.6	30.2	51.3	-1
10/17	13 1/2	137	14.45	19.8	50.6	12.3	7.1	10	1.93	2.72	2.85	3.02	48	40	45	-2	119.5	30.3	52.5	-1.85
10/20	16 1/2	139	14.55	19.8	50.8	12.3	7.15	10	1.95	2.67	2.78	2.90	49.6	41	46.4	-2	119.5	30.4	53.6	-2.3
10/25	21 1 2	142	14.73	19.9	50.9	12.3	7.2	10	1.96	2.55	2.63	2.78	51	41	48	-4	119	31	55	-2.7
10/27	23 1/2	143	14.80	19.8	51.1	12.3	7.2	(16)	1.96	2.49	2.58	2.67	51	41	48	-4	118.8	31	55	-3
11/1	28 1/2	144	—	19.8	51.3	12.3	7.2	15	1.97	2.37	2.49	2.61	52.5	41	49.4	-6	118.6	32	56.5	-3.0
11/5	32 1/2	145	15.13	19.9	51.3	12.3	7.2	17	1.98	2.32	2.40	2.55	53	41	49.5	-6	118.4	32	58.4	-3.2
11/8	35 1/2	146	15.25	14.9	51.3	12.3	7.2	Variable	2.47	2.37	2.45	2.61	53.2	38.2	51	-6	118.4	—	57.8	-3.5
11/11	38 1/2	147	15.35	19.9	51.3	12.3	7.2	33	1.98	2.20	2.35	2.49	53.9	41.4	51.3	-7	118.1	33.1	59.5	-3
11/15	42 1/2	147	15.5	19.95	51.3	12.3	7.2	22	2.00	2.20	2.34	2.43	54	41.5	52	-7	118.5	33.2	59.6	-4.3
11/22	49 1/2	146	15.75	20.0	51.3	12.4	7.2	200-100	2.00	2.20	2.35	2.43	54.7	41.4	52.6	-6	119	33.2	59.7	-4.9
11/30	57 1/2	144	16.0	20.0	51.3	12.5	7.3	25	2.00	2.32	2.36	2.49	55.4	41.9	53.8	-4	119.7	34.8	61.4	-4.9
12/13	70	140	16.5	19.8	51.3	12.3	7.1	15	1.98	2.43	2.55	2.72	54.7	43.0	52.2	0	120	35	59.6	-2.1
12/16	73	138	16.6	19.8	51.3	12.3	7.2	16	1.98	2.49	2.63	2.84	54	43.3	51.8	+1/2	120.5	35	59.6	-2.4
12/19	76	136	16.7	19.8	51.2	12.3	7.1	16	1.97	2.55	2.71	2.90	53.7	43.3	51.0	+2	120.6	35.5	59.4	-2.6
12/27	84	131	17.0	19.8	51.3	12.3	7.2	20	1.99	2.61	2.92	3.21	51.3	43.9	49.4	7	121.8	35.9	—	-3.2
12/30	87	129	17.1	19.8	51.25	12.3	7.2	20	1.97	2.67	2.99	3.27	50.7	44.0	47.8	9	121.8	35.5	54.6	-3.2
1/3/65	91	126	17.25	19.85	51.3	12.3	7.2	22	1.99	2.67	3.06	3.40	49.7	44.4	47	9.4	122	36	53	-3.4
1/6/65	94	124	17.35	19.8	51.3	12.3	7.2	22	1.99	2.72	3.08	3.52	48	44.4	45.2	11	122	35	51.6	-3.3
1/11/65	99	120	17.5	19.9	51.25	12.3	7.2	23	1.99	2.78	–	3.65	44.3	44.6	42.2	13.6	122	34	48	-4
1/17/65	105	115	17.7	19.9	51.3	12.3	7.2	25	1.98	2.78	3.25	3.65	40.3	44.8	38.5	15	122	33.1	43.7	-3.2
1/24/65	112	109	17.9	19.95	51.3	12.3	7.2	24	1.98	2.78	3.20	3.65	34	45	32.4	16.5	122	30.6	37.4	-3.4
1/28/65	116	106	17.9	20.0	51.3	12.3	7.2	25	1.98	2.78	3.13	3.65	29.7	45.1	29	16.3	122	30.4	33.3	-3.3
2/1/65	120	104	18.0	20.0	51.3	12.3	7.2	25	1.98	2.65	3.09	3.65	25	45.3	24.6	15.9	122	29.1	29.3	-3.5
2/4/65	123 1/2	101	–	19.8*	51.3	12.25	7.1	22	1.97	2.67	2.96	3.46	20.9	45	20.2	13.6	121.8	27.6	24.7	-3
2/7/65	126	99	18.0	20.1	51.3	12.3	7.2	26	1.97	2.32	2.88	3.46	19.1	45.4	18.8	13	122	28	24	-3.5
3/5/65	152	80	17.95	20.1	51.3	12.3	7.1	19	1.96	2.55	2.82	3.09	10.5	45.4	11.8	9.3	121	34.1	18.7	-3.0
3/10	157	76	17.9	20.0	51.3	12.3	7.2	21	1.95	2.61	2.91	3.21	10.5	45.4	12.1	12	120.7	36	19.3	-3.0
3/14	161	74	17.8	20.1	51.3	12.3	7.1	20	1.97	2.61	2.92	3.21	10.4	45.2	11.8	13.3	120	36.5	19.5	-3.0
3/18	165	71	17.72	20.1	51.3	12.3	7.1	20	1.97	2.61	2.94	3.27	10.4	45.3	11.8	13	120	38.6	19.9	-3.0
3/22	169	68	17.64	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3/27	174	65	17.5	20.1	51.3	12.3	7.2	20	1.97	2.49	2.95	3.40	11.1	45.0	12.8	10.6	119.7	40.1	20.2	-3.0
4/2	180	62	17.38	20.1	51.3	12.3	7.2	20	1.98	2.43	2.90	3.40	12.1	45.0	13.6	9.2	119	41.4	20.3	-3.0
4/4	182	60	17.28	20.1	51.3	12.3	7.2	20	1.98	2.37	2.87	3.40	12.1	45.0	14.4	9.2	119	41.5	20.5	-3.0

*Intermittent 17.6.
**Cone Filter Number (CFN).

Appendix C

IMP-II Performance Parameter Data Corrected for Analog Oscillator (AO) Calibration Drift

Days > Launch	Date	Correction Factor Applied: A01* -CFN	Correction Factor Applied: A02* -CFN	PP1 (volts)	PP2 (volts)	PP8 (volts)	PP12 (volts)	PP3 (ma)	PP4 (amps)	PP9 Min (amps)	PP9 Ave (amps)	PP9 Max (amps)	PP5 (°C)	PP6 (°C)	PP7 (°C)	PP10 (°C)	PP13 (°C)	PP14 (°C)	PP15 (°C)
T + 24 Min	10/4/64												23.6	36.3	29.4	-10.1	106.8	27.9	28.4
8 1/2 hrs	10/4	0	1	19.6	50.2	12.0	7.0	22	1.88	3.02	3.35	3.65	37	37.2	35.4	- 1.2	—	23.1	39.8
2 1/2	10/6	0	1	19.6	50.4	12.0	7.0	0	1.87	2.96	3.27	3.52	41.5	38	39.5	- 1.2	117	—	44.8
4 1/2	10/8	1/2	1	19.6	50.2	12.0	7.0	0	1.88	2.90	3.16	3.40	41.1	—	—	- 1.8	—	—	—
6 1/2	10/10	1/2	1	19.6	50.2	12.0	7.0	0	1.88	2.90	3.09	3.27	43.6	38.3	41.2	- 1.4	—	26.4	47.6
8 1/2	10/12	1/2	1	19.6	50.2	12.0	7.0	0	1.88	2.84	2.99	3.21	45.2	—	—	- 1.7	—	—	49.9
13 1/2	10/17	1	1 1/2	19.6	—	12.1	6.95	0	1.88	2.64	2.76	2.90	47.2	39.2	43.6	- 6	118	—	—
16 1/2	10/20	1	2	19.6	—	12.0	6.95	0	1.89	2.55	2.67	2.78	48.4	—	—	—	—	27.6	50.7
21 1/2	10/25	1	2	19.7	50.2	12.0	7.0	0	1.89	2.43	2.51	2.67	49.7	40.2	—	—	—	—	—
23 1/2	10/27	1	2	19.6	50.3	12.0	7.0	0	1.89	2.37	2.46	2.55	49.7	—	—	- 8.4	—	—	—
28 1/2	11/1	1	2	19.6	50.6	12.0	7.0	0	1.89	2.26	2.37	2.49	51.1	40.2	47.8	—	—	—	53.2
32 1/2	11/5	2	2	19.6	49.9	12.0	7.0	5	1.88	2.20	2.29	2.43	50.2	—	—	—	—	29.2	—
35 1/2	11/8	2	2	14.6	49.9	12.0	7.0	–	2.38	2.26	2.35	2.49	50.4	—	—	—	—	—	—
38 1/2	11/11	2	2	19.6	49.9	12.0	7.0	22	1.88	2.09	2.23	2.37	51.1	—	—	-11	—	—	—
42 1/2	11/15	2	2	19.6	49.9	12.0	7.0	10	1.88	2.09	2.22	2.32	51.2	—	48.7	—	—	30.4	56.2
49 1/2	11/22	2	2	19.6	49.9	12.1	7.0	–	1.88	2.09	2.23	2.32	—	—	—	—	—	—	—
57 1/2	11/30	2	2	19.6	49.9	12.2	7.1	16	1.88	2.20	2.24	2.37	52.5	40.3	50.4	- 8.4	117.5	32.0	57.9
70	12/13	2	2	19.4	49.9	12.0	6.9	5	1.88	2.32	2.43	2.61	51.7	41.6	48.9	- 4.4	117.9	32.2	56.2
73	12/16	2	2	19.4	49.9	12.0	7.0	5	1.88	2.37	2.51	2.72	-	—	—	—	—	—	—
76	12/19	2	2	19.4	49.9	12.0	6.9	5	1.88	2.43	2.60	2.78	—	-	--	- 2.3	—	32.7	56.0
84	12/27	2	2	19.4	49.9	12.0	7.0	10	1.88	2.49	2.80	3.09	48.5	—	—	+ 2.5	—	33.1	—
87	12/30	2	2	19.4	49.9	12.0	7.0	10	1.88	2.55	2.87	3/15	—	—	—	—	—	--	51.6
91	1/3/'65	2	2	19.5	49.9	12.0	7.0	10	1.88	2.55	2.93	3.27	–	42.9	44.2	—	120	33.2	
94	1/6	2	2	19.4	49.9	12.0	7.0	10	1.88	2.61	2.95	3.40	45.3	–	–	6.6	—	–	48.9
99	1/11	2	2	19.5	49.9	12.0	7.0	11	1.88	2.67	—	3.52	---	—	–	--	—	31.2	46.4
105	1/17	2	2	19.5	49.9	12.0	7.0	12	1.88	2.67	3.13	3.52	37.9	–	–	10.5	–	–	41.5
112	1/24	2	2	19.6	49.9	12.0	7.0	12	1.88	2.67	3.08	3.52	31.9	43.4	30.4	12.0	—	27.9	35.3
116	1/28	2	2	19.6	49.9	12.0	7.0	12	1.88	2.67	3.00	3.52	–	—	—	—	—	—	—
120	2/1	2	2	19.6	49.9	12.0	7.0	12	1.88	2.55	2.96	3.52	24.0	—	–	—	—	—	27.4
123 1/2	2/4	2	2	—	49.9	12.0	6.9	10	1.88	2.55	2.84	3.33	--	—	—	—	—	—	—
126	2/7	2	2	19.6	49.9	12.0	7.0	13	1.88	2.20	2.76	3.33	17.3	43.8	17.0	8.6	120	25.2	22.2
152	3/5	2	2	19.6	49.9	12.0	6.9	8	1.88	2.43	2.70	2.96	8.6	43.8	10.0	4.8	119.1	31.3	16.9
157	3/10	2	2	19.6	49.9	12.0	7.0	8	1.88	2.49	2.79	3.09	8.6	—	—	7.6	118.6	33.2	17.5
161	3/14	2	2	19.6	49.9	12.0	6.9	8	1.88	2.49	2.80	3.09	8.5	—	10.0	8.9	117.9	—	17.7
165	3/18	2	2	19.6	49.9	12.0	6.9	8	1.88	2.49	2.82	3.15	8.5	—	10.0	8.6	117.9	35.7	18.1
169	3/22	2	2	19.6	49.9	12.0	–	8	1.88	—	—	—	—	—	—	—	—	—	—
174	3/27	2	2	19.6	49.9	12.0	7.0	8	1.88	2.37	2.83	3.27	9.4	—	11.0	5.8	117.5	37.4	18.4
180	4/2	2	2	19.6	49.9	12.0	7.0	8	1.88	2.32	2.78	3.27	10.4	—	11.8	4.7	116.8	38.7	18.5
182	4/4	2	2	19.6	49.9	12.0	7.0	8	1.88	2.26	2.75	3.27	10.4	43.4	12.7	4.7	116.8	38.8	18.7

*PP1 - 7, Analog Oscillator 1, PP8 - 15, Analog Oscillator 2, Comb Filter Number (CFN).

Appendix D

IMP-II Shadow Times

Pass	Date	Start Time (UT)	Duration (min)
LAUNCH	10/4/65	0345	20.3
1*	10/5	1425	22
2	10/7	0106	22
3	10/8	1147	22
4	10/9	2228	22
5	10/11	0908	22
6	10/12	1948	22
7	10/14	0628	23
8	10/15	1709	23
9	10/17	0349	23
10	10/18	1430	23
11	10/20	0110	23
12	10/21	1151	23
13	10/22	2232	23
14	10/24	0912	23
15	10/25	1952	23
16	10/27	0632	23
17	10/28	1712	23
18	10/30	0353	23
19	10/31	1433	23
20	11/2	0114	23
21	11/3	1155	23
22	11/4	2235	23
23	11/6	0916	23
24	11/7	1956	23
25	11/9	0636	23
26	11/10	1716	23
27	11/12	0356	23
28	11/13	1436	23
29	11/15	0117	23

*End of orbit 1, etc.

IMP-II Shadow Times (Continued)

Pass	Date	Start Time (UT)	Duration (min)
30	11/16	1158	23
31	11/17	2239	23
32	11/19	0919	23
33	11/20	1959	22
34	11/22	0639	22
35	11/23	1719	22
36	11/25	0359	21
37	11/26	1439	21
38	11/28	0120	21
39	11/29	1200	21
40	11/30	2241	20
41	12/2	0922	20
-	12/3 (Moon Shadow)	1633	68*
42	12/3	1954	19
43	12/5	0634	19
44	12/6	1714	18
45	12/8	0403	17
46	12/9	1443	17
47	12/11	0123	16
48	12/12	1204	15
49	12/13	2245	14
50	12/15	0926	12
51	12/16	2007	10
52	12/18	0648	8
53-125	12/19/64 - 4/4/65	-	0
126	4/5/65	0142	2 hrs 38 min †
127	4/6	1203	3 hrs 56 min †
128	4/7	2250	4 hrs 23 min †
129	4/9	0954	4 hrs 20 min †
130	4/10	2113	3 hrs 50 min †
131	4/12	0851	2 hrs 45 min †
132	4/13	-	0

*Includes only about 2 or 3 minutes of total darkness.
†Total darkness, exclusive of penumbra.

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